Archaeological
Institute
of America

ARCHITECTURAL REFINEMENTS IN ITALIAN CHURCHES [1]

In 1895 the Brooklyn Institute of Arts and Sciences authorized and supported, on behalf of its then projected and now existing Museum, the making of a series of architectural surveys of Italian mediaeval churches and cathedrals. It was the purpose of these surveys to continue an investigation which had been originally undertaken in 1870, the results of which were published four years later.[2]

The publication of 1874 was generally limited to Pisa, but was of such a character as to preclude the idea that the phenomena described could have been locally limited to that town. It announced as constructive refinements a series of inconspicuous curves, obliquities, and asymmetrical measurements in the main lines and surfaces of the Pisa Cathedral which had never been previously catalogued or described. It announced other irregularities as constructive refinements which had been otherwise supposed to be accidental — notably, the overhanging façade, which was supposed to be accidental by Mr. Ruskin.[3] A system of illusion in perspective was also announced as having been employed at Pisa, notably in the interior of the Cathedral, and in the Church of S. Stefano, outside the walls, where this system was first observed.

[1] The matter of this Paper was laid before the annual meeting of the Archaeological Institute, in New York, December 27, 1901. The illustrations are accurate pen-and-ink drawings from photographs of the Brooklyn Institute survey of 1901, which were shown at this meeting.

[2] *Scribner's Magazine*, August, 1874, 'A Lost Art,' by W. H. Goodyear.

[3] *Seven Lamps of Architecture*, 'The Lamp of Life,' p. 158 (Sunnyside ed., 1880).

This publication had thus catalogued a series of constructive variations in measurements, dimensions, and alignment, of a much more varied, more extended, and more persistent character than those which had been noticed by Mr. Ruskin in the *Seven Lamps of Architecture* and in the *Stones of Venice.* The latter were limited to variations of intercolumniation or of arch construction.

These various announcements tended to establish a new point of view in the study of mediaeval architecture and to vindicate for some of its monuments a quality of subtlety which had so far been considered to hold only of the temples of the Greeks. The original advice to publish was given by Jacob Burckhardt, then of the University of Basle, and during his lifetime the leading German authority on the general art history of Italy. He personally assured the writer of his ignorance of the facts which had been discovered; and that these facts were not then known to other students of mediaeval architecture is attested by the standard publications of that date, as well as by others which are much more recent.

The Brooklyn Institute surveys of 1895 covered a period of six months, and included observations in all the well-known cathedrals and churches of Italy, as well as in many of the minor churches and in some rarely visited localities.

A very considerable number of churches and cathedrals were found to have no subtleties of construction. The individual mention and cataloguing of the buildings which are destitute of refinements will be one of the matters for publication in a book which is now in preparation and for Memoirs which have been announced by the Brooklyn Institute Museum. These publications will have the importance of showing that the less pretentious or more roughly and carelessly built churches are those generally destitute of refinements. In other words, the well-known and very prevalent irregularities, which are due to the use of heterogeneous materials from ancient buildings, or which are due to indifference to regularity and to rough construction, are insufficient explanations of the phenomena.

Many of the positive results of the surveys of 1895 have been published in the *Architectural Record Quarterly Magazine* (1896–1898).[1]

In the summer of 1901 these investigations were continued, with results which it is the design of the present article to summarize. The expense of this work was supported by a contribution of $500 from Mrs. August Lewis, of New York, who had contributed the same sum toward the surveys of 1895. These had been otherwise supported by a contribution of $1500 from the Brooklyn Institute and by a contribution of $1500 from the writer.

The special purpose of the visit to Italy of 1901 was partly to submit the phenomena, already announced as existing in St. Mark's at Venice and in the Pisa Cathedral, to the engineering architects at present in charge of those buildings and to obtain their verdict on the constructive facts. Their certificates are appended (pp. 195, 196). Another purpose of the trip was to obtain photographs and measures, and to make more careful record, of some important facts which were insufficiently substantiated.

The remarkable discovery had been made, in 1895, that delicate architectural curves were occasionally constructed by the mediaeval Italian builders, of a character which suggested a traditional inheritance, possibly through Byzantine sources, from ancient Greek art. These more delicate curves were not discovered in 1870, although there are many of them in the Pisa Cathedral. The suggestion of a historical connection

[1] Vol. VI, no. 1, 'Optical Refinements in Mediaeval Architecture'; vol. VI, no. 2, 'Perspective Illusions in Mediaeval Italian Churches'; vol. VI, no. 3, 'Constructive Asymmetry in Mediaeval Italian Churches'; vol. VI, no. 4, 'A Discovery of Horizontal Curves in Mediaeval Italian Architecture'; vol. VII, no. 1, 'A Discovery of the Entasis in Mediaeval Italian Architecture'; vol. VII, no. 2, 'An Echo from Evelyn's Diary'; vol. VII, no. 3, 'The Problem of the Leaning Tower of Pisa.'

See also vol. IV, no. 4, 'A Discovery of Horizontal Curves in the *Maison Carrée* at Nîmes,' and vol. IX, no. 1, 'Horizontal Curves in Columbia University.' The Smithsonian Reports for 1894 have republished the article on the *Maison Carrée*. See also the *American Journal of Archaeology*, First Series, X, no. 1.

with ancient Greek art through Byzantine sources was, however, originally made in 1874. The peculiar character and use of these curves were of such a nature as to react on some of the explanations which have been in vogue regarding the Greek curves, so as to suggest a preference for some of these explanations as compared with others.

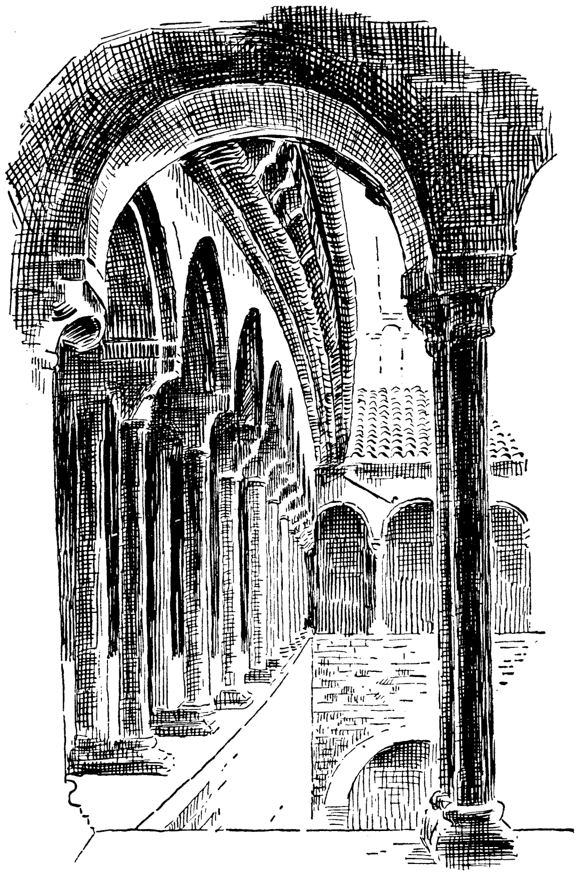

FIGURE 1.—HORIZONTAL CURVES IN PLAN, IN THE CLOISTER OF THE CELESTINES AT BOLOGNA.
(Drawing from a Brooklyn Institute photograph.)

A peculiarly important instance of constructive curves had been surveyed and photographed in 1895, at Bologna, in the twelfth century Cloister of the Celestines. The negatives were, however, broken in transit before prints had been taken from them. Without such photographs it was not possible to give convincing publicity to this discovery. In 1901 new photographs were made on all sides of the Cloister of the Celestines, some of which are published herewith (Figs. 1

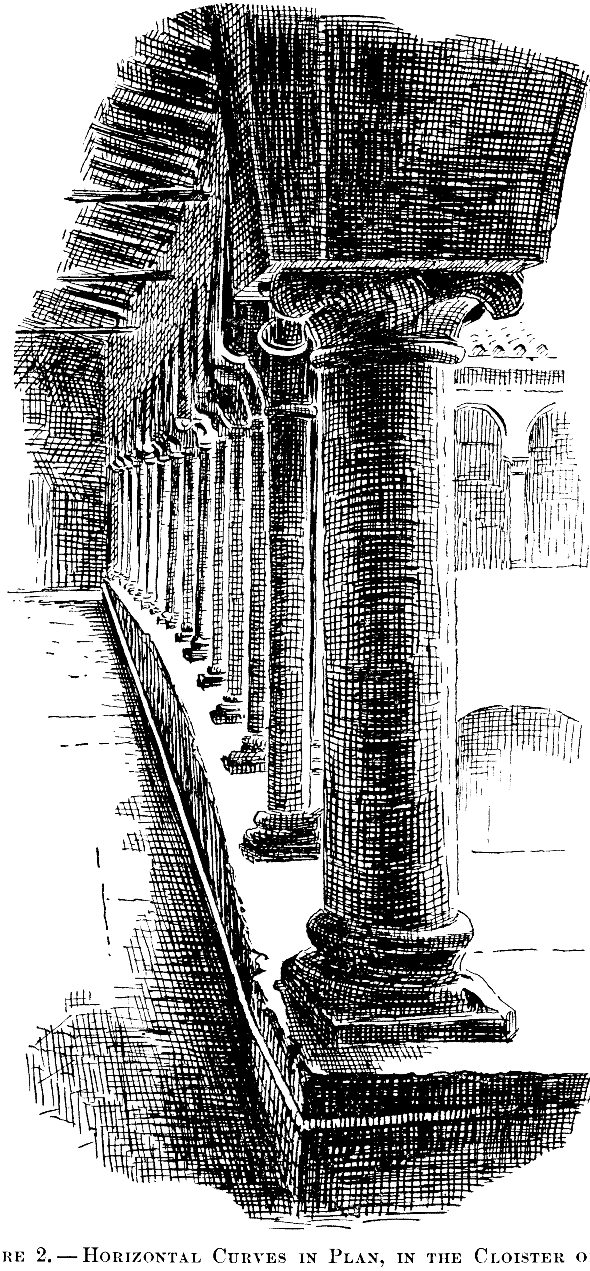

FIGURE 2.—HORIZONTAL CURVES IN PLAN, IN THE CLOISTER OF THE CELESTINES AT BOLOGNA.

(Drawing from a Brooklyn Institute photograph.)

and 2). The curves appear much stronger in the photograph than they do in the building, where they are so discounted by the eye into ordinary effects as to be inconspicuous. The arcades of the cloister are about fifty feet in length on each side. The amount of the curve, which is practically uniform on all sides, is about five inches on each side, as measured on the parapet of the second story. There

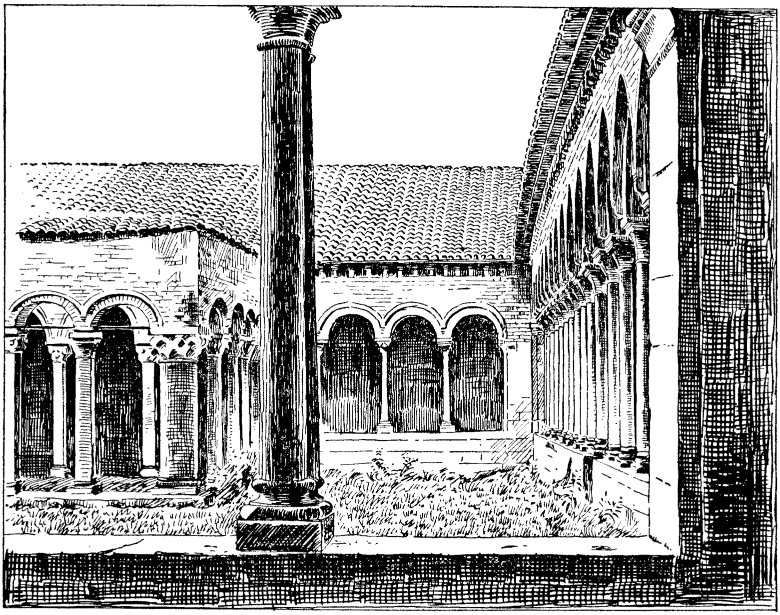

FIGURE 3. — HORIZONTAL CURVES IN PLAN, IN THE CLOISTER OF S. ZENO AT VERONA.

(Drawing from a Brooklyn Institute photograph.)

are slight curves in the foundations on all sides of the cloister, and they are well accented in the lower part of the first story.

Another important and similar instance was also surveyed and photographed in 1901, in the Cloister of S. Zeno at Verona (Fig. 3). An observation had been previously made here by a member of our party, in 1895, but without measures or photographs.

The great importance of these instances is that they offer satisfactory proof regarding the constructive intention of the builders. The curves of the Verona cloister are uniform in measurement and character on three sides of the court. They are not found on the fourth side, which is broken by a construction projecting into the court (Fig. 3). The dimensions of the court are about 72 × 80 feet in the length of the colonnades. At the foundations of the parapets the curves measure on the three sides (west, south, and east), respectively, 0.12, 0.11, 0.13 (foot decimals). At the bases of the columns they measure, respectively, 0.10, 0.15, 0.12 feet. In the cornice they measure about 0.40 feet, or approximately, five inches.

With the exception mentioned for Verona, all the sides of the cloisters at Verona and Bologna are laid out in curves which are convex in plan to the centres of the courts. Such uniformity of direction eliminates the possible objection that carelessness of construction is a sufficient explanation. Another objection as to constructive intention is occasionally based on possible settlement of foundations; but these curves are in plan, and not in elevation.

A third possible objection as to constructive intention is connected with the action of thrust from a vaulting. In vaulted cloisters the ends of the cornices are "tied in" by the resistance of the arcades where they meet the thrust of the vaulting at right angles, whereas the thrust of the vaulting at the centre is not resisted by an opposing force and there is a consequent tendency to bulge outward at this point. But at Bologna, where the cloister is two-storied, the curves begin at the foundations and in the lower walls of the building; and at Verona the curves begin in the foundations of the parapets, and they are also found in the bases of the columns which rest on the parapets. Moreover, in both cases the ceilings of the cloisters are of timber, and not vaulted. The lower story at Bologna has also timber ceiling on the side from which the photographs are taken. The three other lower stories are vaulted, but there are no curves in the inner sides of the walls. These

various facts offer convincing proof that constructive curves were employed by Italian mediaeval builders, and it is self-evident that they must have been employed with an aesthetic purpose. The question as to what this aesthetic purpose was, can hardly be considered debatable when the following facts are considered.

In both cloisters the effect of the curves must be considered as intended from the standpoint within the cloister corridors, as well as from the standpoint in the court. In the corridors the curves are concave to the eye, but they are seen both in the lines above the level of the eye, and in the parapets below the level of the eye. Optically considered, the effects tend to be translated by the eye into the effect of curves in elevation. Concave curves above the eye appear to be descending curves in elevation; *i.e.* they appear to sag at the centre; while concave curves below the eye tend to appear as rising curves in elevation. On the other hand, as seen from the court, the convex curves above the eye, of the cornices, tend to appear as rising curves in elevation; whereas, the convex curves below the eye tend to appear as curves which sag downward. Under these circumstances no theory appears tenable, excepting that the curve was preferred to the formalism and rigidity of straight lines. This is an explanation which has already appeared satisfactory for the Greek curves to many experts, notably Burckhardt, Kugler, and Schnaase.[1]

Theories of a purpose of optical correction which have been offered for the Greek horizontal curves,[2] and to the effect that they were originally intended to correct an appearance of downward sagging, in lines which are actually straight, cannot be applied to these cloisters, because half of the curves employed actually do tend to sag, in optical effect. Hence if a historic connection with the Greek curves be admitted, it

[1] See, for instance, Burckhardt, *Der Cicerone*, p. 4.

[2] Penrose, *Principles of Athenian Architecture*, 1851, p. 78: "There can be little doubt that the origin of the horizontal curve was to obviate a disagreeable effect produced by the contrast of the horizontal with the inclined lines of a flat pediment."

would appear that these theories would also have to be abandoned, or modified.

Such serious objections already exist, however, to the theories of Penrose, as advanced for the Greek curves, that they appear untenable even without this new and additional argument.

For instance, the Brooklyn Institute Survey of 1895 has established the existence of curves in elevation on the sides of the temple of Concord at Girgenti, but it has also proven that there are no curves under the gables. This is apparently an unanswerable argument against the theory of Penrose that the Greek curves originated in the desire to avoid an effect of downward sagging in the entablature under the gable. It also antagonizes the view that the Greek curves were intended to correct other effects of sagging;[1] for the tendency to an effect of sagging is certainly greater under the gable than it is on the flanks of the temple. It is doubtful if such an effect exists at all on the upper lines of the sides of a Greek temple. At close range it certainly does not exist. (It has never been suggested by Penrose that it exists at all.) Other unanswerable objections to the theories of Penrose have been advanced by Dr. Guido Hauck.[2] This publication very effectively supplements and largely supplants that of Thiersch,[3] who had already successfully shown the weak points of the theory of correction for the gable. It should, however, by no means be overlooked that Penrose must rank for all time as having by his surveys furnished the proofs for the existence of the curves in Greek architecture, although he was not the original discoverer of them. It must also be remarked that Penrose has not urged his theories as being final or as being the only ones possible, and he has himself mentioned aesthetic reasons as

[1] Burnouf, *Revue de l'Architecture*, 1875, p. 146, and Thiersch, as below quoted.

[2] Guido Hauck, *Die Subjective Perspective und die Horizontalen Curvaturen des Dorischen Styls.* Stuttgart, 1879, Konrad Wittwer. Dr. Hauck was in 1879 Professor of Descriptive Geometry in the Royal Technical High School of Berlin.

[3] 'Optische Täuschungen auf dem Gebiete der Architectur,' in the *Zeitschrift für Bauwesen,* XXIII. Berlin, 1873, Ernst & Korn.

being probably contributory causes for the use of curves on the flanks of a temple.[1]

The curves of the quoted cloisters have a remarkable analogy with those of the second court of the Egyptian temple of Medinet Habou,[2] but they also differ from these. Both are alike in the important point that they are in plan, as distinct from curves in elevation, and in both cases they are convex to the centre of the court. But at Medinet Habou the curves are not appreciable in the lines of the bases of the columns, and there are no parapet curves to be considered. At Medinet Habou it might easily be conceded that the effect was solely contrived for the point of view in the court, where the curves are convex to the spectator and above the level of the eye. For all such points the optical effect of the curves is equivalent to that of a curve in elevation. In the case of the cloister curves, it has been shown that they appear to be of equal importance on the concave sides as well as on the convex sides, and that they appear to be of equal importance, whether seen from above or below the level of the eye.

The remarkable ignorance of the experts who have made publications about the Greek curves, of the existence of the curves at Medinet Habou has been noted by me in another publication.[2] This ignorance is the more remarkable because the original discovery of the Greek curves by Pennethorne in 1837, was owing to his previous discovery of the Egyptian curves. But although the Egyptian curves were observed by Pennethorne in 1833, they were not made known to the world until 1878.[3] It is easy to understand how they had not come to the knowledge of Hauck in 1879, and the publication of Thiersch was still earlier, in 1873. Penrose published in 1851.

The mere existence of these Egyptian curves is sufficient to neutralize the gable theory of Penrose. The whole argument of the important publication of Hauck is also based on the

[1] See p. 79 of his cited work, referring to the beauty of a curved line.

[2] *Architectural Record Quarterly*, IV, no. 4.

[3] Pennethorne, *Geometry and Optics of Ancient Architecture*, 1878, p. 84.

assumption that horizontal curves were confined to the Doric style of Greek temple architecture, and his interesting argument is therefore also neutralized by the existence of the Medinet Habou curves; provided it be conceded that the Greek curves are related to the Egyptian and that some common explanation ought to be found for both.

I have previously published personal observations regarding other Egyptian curves, notably at Edfou.[1] It is probable that the curves of the Egyptian temple courts will be more carefully considered when their analogies with those of mediaeval Italy have been made apparent. The probability that the Egyptian curves were the ancestors of the Greek curves leads to the remark that the Greek curves in plan have also so far been generally neglected by experts. Jacob Burckhardt is the only critic who has mentioned the curves in plan on the flanks of the temple of Neptune at Paestum as having an aesthetic purpose.[2] Their existence is unknown to the work of Penrose, and is presumed to be accidental by Thiersch. These curves have been photographed for the first time by the Brooklyn Institute Survey of 1895, and there appears to be no reason for doubting their constructive character as asserted by Burckhardt. The curves of the Maison Carrée at Nîmes, which were discovered by me in 1891, are also curves in plan.[3]

The following points may therefore be summarized as being of importance in connection with the curves in the cloisters of Verona and Bologna:

(*a*) They demonstrate that architectural refinements were employed in mediaeval architecture, and that they were not confined to the Greeks.

(*b*) The refinements cannot have been employed for the correction of optical illusion. They must therefore represent a positive aesthetic preference for delicately curved lines as

[1] *Architectural Record Quarterly*, vol. IV, no. 4.

[2] Jacob Burckhardt, *Der Cicerone*, p. 4.

[3] *Architectural Record Quarterly*, vol. IV, no. 4; Smithsonian Report for 1894, pp. 573–588; *American Journal of Archaeology*, First Series, vol. X, no. 1.

more pleasing than mathematically straight lines in architectural colonnades.

(*c*) The opinions of the German and French experts who have not favored the view that the Greek curves were originally designed to correct a sagging effect are supported by this discovery.[1]

(*d*) The constructive curves in plan of Egyptian temple courts offer important analogies with the curves in the cloisters of Verona and Bologna.[2]

[1] Boutmy, *Le Parthenon et le Génie Grec*, has advocated the theory that the purpose of the Greek curves was to accent the curvilinear perspective. This contention has been much more ably and explicitly developed by Hauck. It was originally suggested by Hoffer (*Wiener Bauzeitung*, 1838), but Hoffer also considered the curves as giving life and beauty to the building and as superior to the more monotonous and colder effects of mathematically straight lines. A consensus of authorities is therefore to be noted (Burckhardt, Kugler, Schnaase, Hauck, Boutmy, Hoffer), who, though differing among themselves, still unite in not advocating the theory of correction. Reference to the theories of curvilinear perspective has been otherwise avoided in this Paper as unduly increasing its length. It must certainly be admitted that horizontal curves may have been used in different cases for different purposes both in Greece and mediaeval Italy, and there are cases of which it might be asserted that more than one purpose might be admitted. It is quite clear, however, that the cloister curves do not come inside the theories which have been advanced for curvilinear perspective.

[2] The twelfth century Cloister of Sassovivo, near Foligno, offers an instance of very regular and very delicate curves in plan, convex to the court on all sides.

These curves are in the upper cornice lines, and they do not appear in the parapets. As this cloister is vaulted, we cannot positively assert that these curves have not been produced by thrust. The larger cloister of the Certosa of Pavia shows very delicate curves in the parapets and in the lines of the bases of the columns. They are in plan and convex to the court on all its sides, and amount to about 2½ inches in a length of 130 paces. They are of slightly irregular character, but are perfectly sensible to the eye. A successful photograph was made here last summer. The original observation was made in 1895. No curves are visible here in the cornice lines. In 1901 I reëxamined the cloisters of St. John Lateran and S. Paolo Fuori, at Rome, which are quoted in the *Architectural Record Quarterly* (VII, no. 1). The rough work of the masonry, the possibility of thrust, and the interference of the drain pipes with the line of vision (in the case of S. Paolo Fuori) led me to the conclusion that these are doubtful instances for constructive curves. (Many cloisters were examined both in 1895 and 1901, in which the lines were quite straight, both in the cornice and the parapets.) My own doubts as to the Roman cloisters named are connected with the question whether curves in the cornice lines were not sometimes worked in by constructive leaning forward of columns near the centre of each side. If some instance of such working in of a curve was conclusively proven,

The curves in cloisters are, however, only one phase of the use of constructive curves in Italian mediaeval architecture. I have already published many of these instances, which are especially numerous in the Pisa Cathedral and in St. Mark's at Venice.[1] Those which were discovered in 1895 were not at that time brought to the attention of the architects in charge of the buildings. In 1901 I submitted the discovered facts to the engineering architects who were respectively in charge of St. Mark's and of the Pisa Cathedral, and secured from them certificates verifying the constructive and intentional use of curves in these buildings. These certificates are appended. It will appear from Commendatore Saccardo's certificate that the concave curve in plan of the façade of St. Mark's is known to him as an aesthetic device. (It was published by me in the *Architectural Record*, VI, no. 4, p. 489.) It may not be amiss to say here, that the earliest observed case of constructive mediaeval curves is in S. Apollinare Nuovo at Ravenna (sixth century).[2] The latest observed case of classic curves is that of the Maison Carrée at Nîmes.

The survey of 1901 was also successful in securing convincing evidence for the existence of constructive vertical curves in Italian mediaeval churches. Vertical curves are very generally exposed to the suspicion that they have been produced by thrust from vaultings or arches, because they frequently appear in the piers of vaulted churches at points where these piers are exposed to thrust from the aisle vaultings. In 1895 I had observed instances in the Cathedral of Vicenza which were not exposed to this suspicion, but the observation was hurried, and no photographs were taken. In 1901 the facts were observed with greater deliberation, and photographs were successfully made (Fig. 4).

it would react on my views about S. Paolo Fuori. There are some indications that this was done here, but the question is still in the balance. This question is also important for Sassovivo, where the columns distinctly lean outward toward the centres. The appearances here, to my observation (1895), favored the belief in a constructive lean.

[1] *Architectural Record Quarterly*, vol. VI, no. 4. [2] *Ibid.*

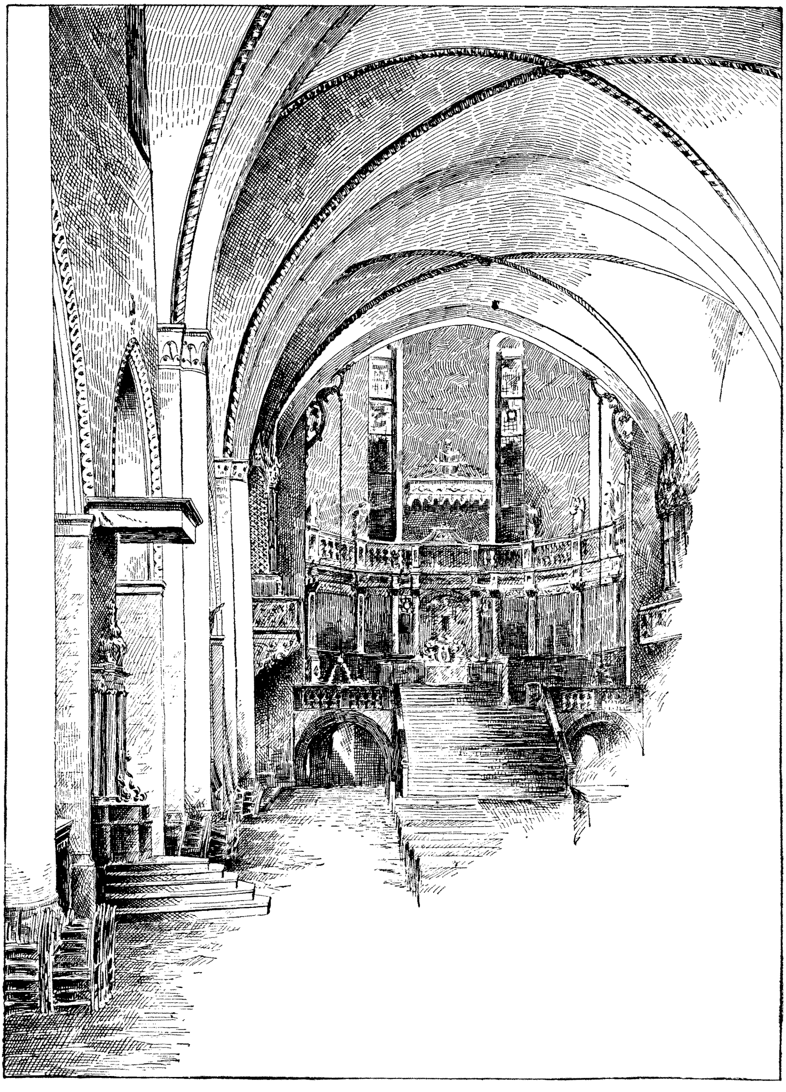

FIGURE 4. — DELICATE VERTICAL CURVES IN THE PILASTERS OF CHAPEL WALLS IN THE CATHEDRAL OF VICENZA.

(Drawing from a Brooklyn Institute photograph.)

In the Cathedral of Vicenza there are no aisles. Chapels separated by walls at right angles to the line of the nave, and about twenty-five feet deep, take their place. The pilasters, which face these walls fronting on the nave, are built in very delicate vertical curves.

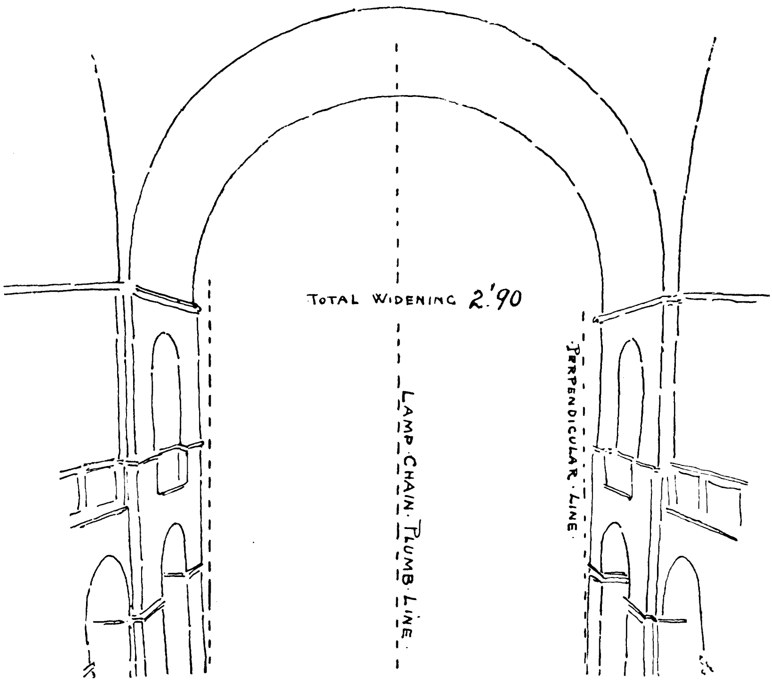

FIGURE 5. — THE OUTWARD SPREAD OF THE PIERS IN ST. MARK'S AT VENICE.[1] From the *Architectural Record Quarterly*, vol. VII, no. 2. (Tracing from a Brooklyn Institute photograph.)

An important instance of vertical pilaster curves which are not exposed to the suspicion of thrust was also surveyed and photographed in S. Paolo Ripa d' Arno, at Pisa, in 1901. It was announced in 1874, together with the vertical curves in the great pilasters at the junction of nave and transept in the Pisa Cathedral.

[1] See the appended certificate of Commendatore Pietro Saccardo, p. 195.

The survey of 1895 discovered a certain number of Italian vaulted churches in which the piers of the nave, and sometimes the exterior walls, were constructively leaned outward.[1] These leans are so delicate as to be inconspicuous, and may have had the purpose of correcting for the interior an appearance of contraction, or narrowing in, of the upper vertical lines of the church, which would be due to the natural perspective. Such inclinations are, however, so obviously liable to be of accidental occurrence as a result of thrust, or of the settlement of foundations, that any announcements of their constructive existence are peculiarly and justly exposed to scepticism. The facts are certainly very extraordinary, but all possible doubts have, notwithstanding, been removed by the observations of 1901. The engineering architect of St. Mark's has examined with me the facts as regards that church (Fig. 5), and his certificate is appended. The given device was even employed by Palladio in S. Giorgio Maggiore at Venice, and photographs have been taken in this church showing the phenomena under conditions which preclude any suggestion of thrust or settlement.

The Gothic church of S. Agostino at Orvieto has walls which lean outward against buttresses, of the same date and construction, which lean inward. These have been photographed (Fig. 6).

The Church of S. Lorenzo at Vicenza has walls which lean outward against buttresses, of the same date and construction, whose exterior lines are perpendicular. These have been photographed. The interior walls lean out not less than six inches in twenty-five feet. The walls are four feet thick, and the buttresses are three feet wide at the base.

Peculiarly important observations of the given refinement were made in 1895 in S. Ambrogio and S. Eustorgio at Milan and in S. Michele at Pavia, but in such haste that these observations were unsupported at that time by detailed measurements and photographs. In all these churches the aisles are

[1] *Architectural Record Quarterly*, vol. VII, no. 2, 'An Echo from Evelyn's Diary.'

bordered by chapels with walls of very considerable depth, faced by pilasters which are not exposed to thrust. The

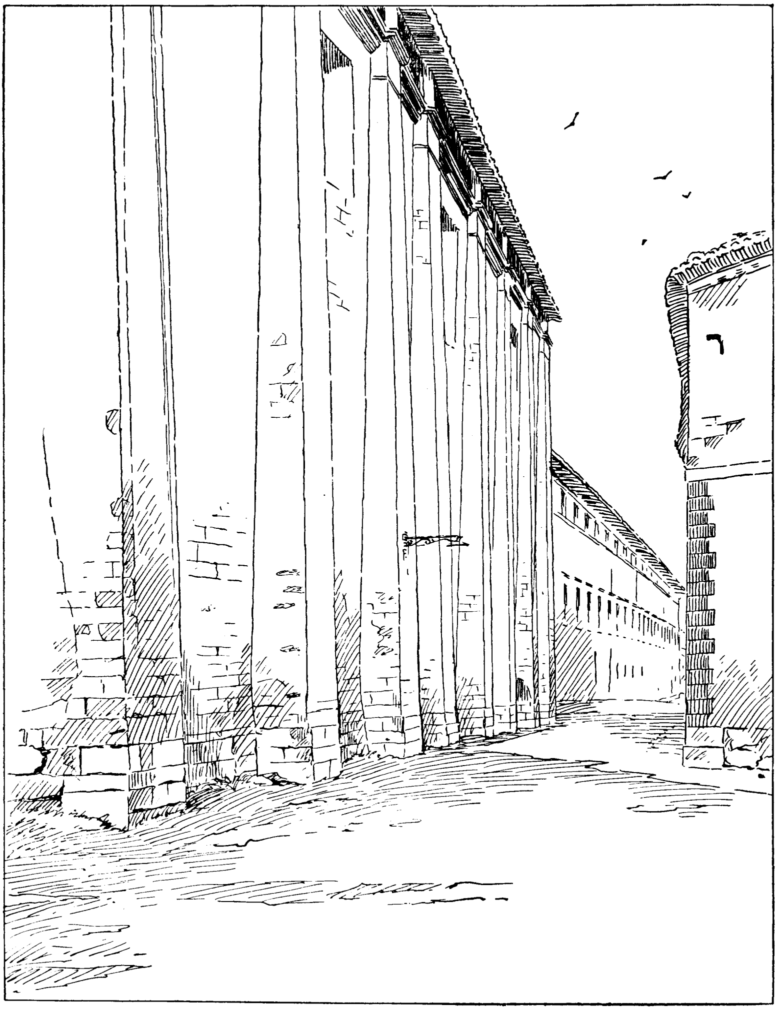

FIGURE 6. — S. AGOSTINO AT ORVIETO.
The walls lean out against buttresses of the same date and construction which lean in. (Drawing from a Brooklyn Institute photograph.)

outward leans have now been plumbed, in all these pilasters, and excellent photographs have been made of the phenomena

in the Milan churches (Figs. 7, 8). In the right aisle of S. Ambrogio six pilasters have an average outward lean of 4 inches in 13 feet. The maximum lean is $5\frac{1}{4}$ inches; the minimum lean is $2\frac{1}{2}$ inches. It is the minimum lean which is shown by the plumb-line in Fig. 7. The chapel walls are 21 feet deep. In S. Eustorgio the average outward lean of the chapel pilasters is 4 inches in a height of 13 feet. As the phenomena are constant in all pilasters, and uniform in three separate churches which have these side chapels, there can be no doubt of constructive intention.

Among my original observations of 1870 and original announcements of 1874, regarding the Pisa Cathedral, it was observed and announced that the façade was inclined forward by construction. The upper part of the façade, however, bends back to the perpendicular (Fig. 9). The masonry measurements taken in 1895 placed this announcement beyond any doubt in my own mind and that of my assistants, but the measurements, not having been published, were consequently not brought to the attention of Italian experts. Publication was subsequently made.[1] In 1901 I went over the cathedral with Signor Annibale Messerini, the architect now in charge, and his certificate is appended (p. 195). The remarkable facts are now established beyond dispute. Photographs were also taken, in 1901, of certain features of the construction of the façades of S. Michele at Pavia and of S. Ambrogio at Milan which establish a similar constructive intention in these façades. Both of them curve back to the perpendicular, and are erect in the upper portion (Figs. 10, 11).

Of still greater interest is the discovery of a constructive leaning façade in the Renaissance Church of S. Ambrogio at Genoa, dating about 1580. The present engineering architect in charge of this church has himself built the second story of the façade. His certificate for the constructive lean of the lower portion is therefore of great interest. This certificate is appended (p. 194). The facts regarding S. Ambrogio

[1] *Architectural Record Quarterly*, vol. VII, no. 3.

FIGURE 7. — RIGHT AISLE OF S. AMBROGIO, MILAN.

The plumb-line shows an outward lean of 2½ inches in 13 feet. The maximum lean in this aisle is 5¼ inches. The average lean is 4 inches. (Drawing from a Brooklyn Institute photograph.)

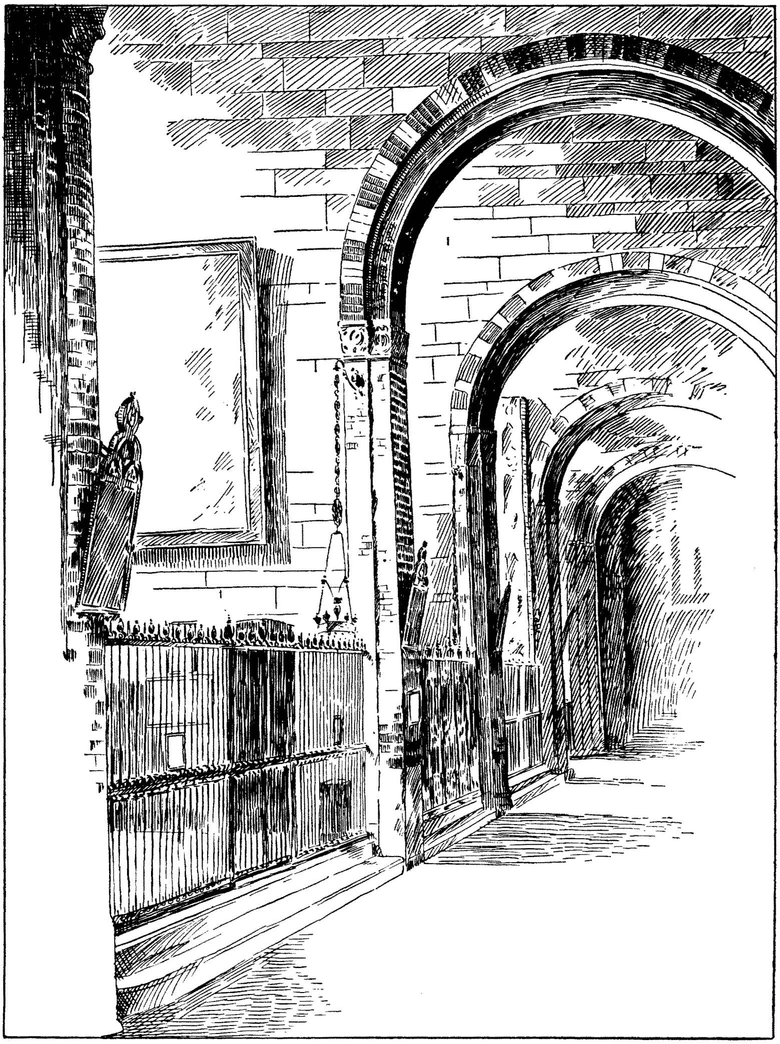

FIGURE 8.—RIGHT AISLE OF S. EUSTORGIO, MILAN, LOOKING TOWARD THE FAÇADE.

The average outward lean of the pilasters is 4 inches in 13 feet. (Drawing from a Brooklyn Institute photograph.)

were observed on the day of sailing from Genoa, in 1895, and could not be verified at that time (Figs. 12, 13). The lean amounts to about 8 inches in about 56 feet.

The purpose of these various leaning façades may have been the same as that which leads us to tip a picture on a wall, that is, to avoid foreshortening. The return to the perpendicular in the upper façade at Pisa, at Pavia, and at Milan, is probably due to considerations of stability, and it may have also been connected with the preference of certain mediaeval builders for bends and curves of architectural lines and surfaces. A similar construction in the façade of Notre Dame at Paris was announced by me at the Philadelphia General Meeting of the Archaeological Institute, in 1900.[1]

The lower columns of the façade of St. Mark's at Venice were observed by me, in 1870, as having a constructive forward lean (Fig. 14). The wall from which they project is perpendicular. Announcement of this was made after the surveys of 1895,[2] but successful photographs were not then obtained. The picture now reproduced is one of four which are all good. It is, however, of more importance to state that this phenomenon has now been verified as constructive by the certificate of Commendatore Pietro Saccardo. The upper line of columns is perpendicular. The motive would appear to have been the preference for a bent or curving vertical line. If foreshortening alone were considered, the upper line of columns would also have leaned forward. This observation may throw light on the motive of the other leaning façades, just quoted, which bend back to the perpendicular. The amount of the lean is from 2 inches to $3\frac{1}{2}$ inches in a height of $9\frac{1}{2}$ feet. No columns are perpendicular, excepting those at the restored southwest angle.

Measurements were made in 1901 which probably determine the much debated question regarding the cause of the inclination of the Leaning Tower of Pisa. They support the obser-

[1] *American Journal of Archaeology*, V (1901), p. 12.
[2] *Architectural Record Quarterly*, vol. VII, no. 3.

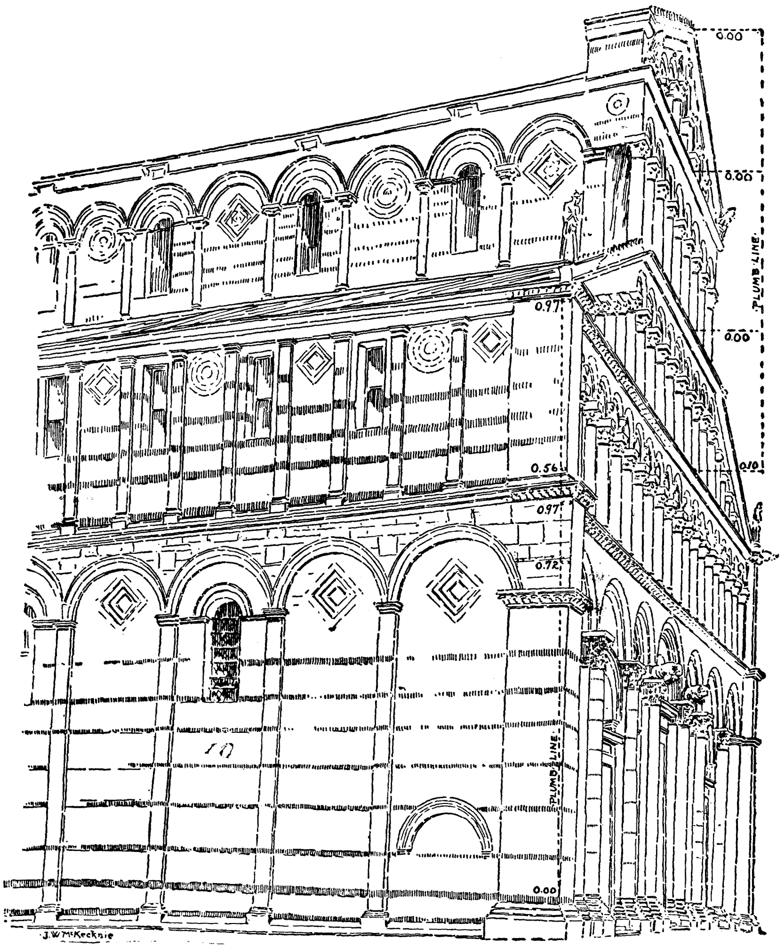

FIGURE 9. — THE LEANING FAÇADE OF PISA CATHEDRAL.

From the *Architectural Record Quarterly*, vol. VII, no. 3.[1] Measurements in foot decimals are entered on the drawing. The entire amount of the inclination is about 17 inches. (Tracing from a Brooklyn Institute photograph.)

[1] See appended certificate of Signor Annibale Messerini.

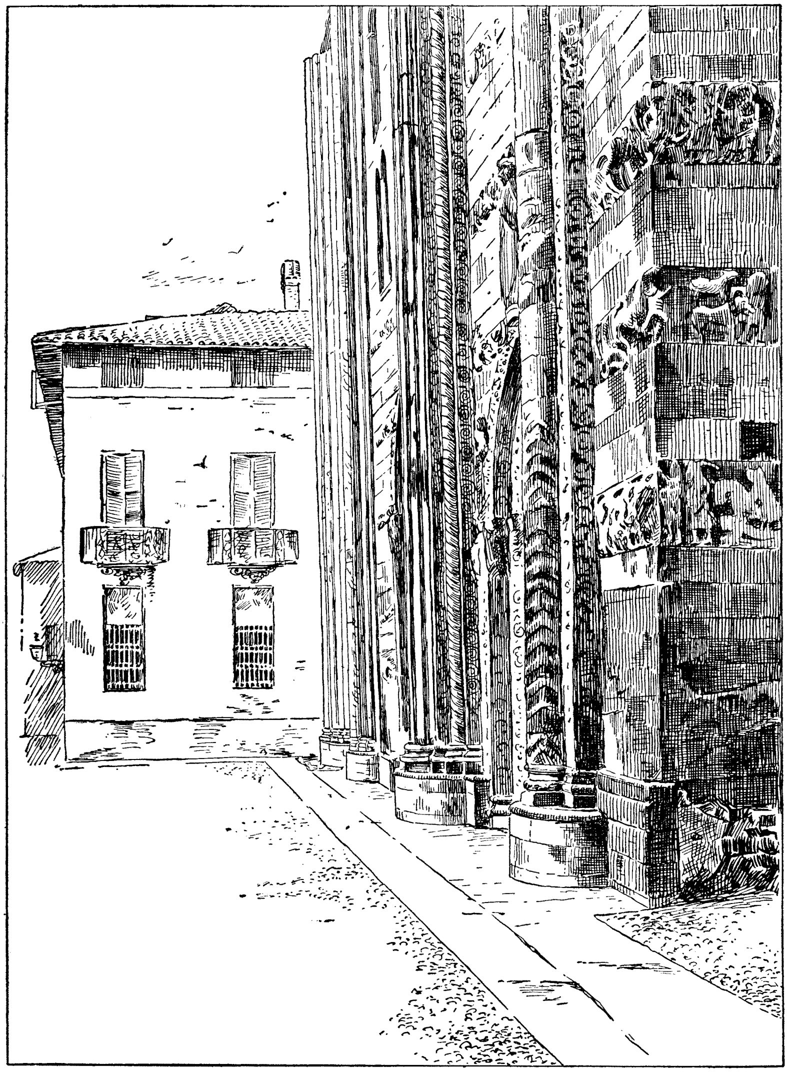

FIGURE 10.—THE LEANING FAÇADE OF S. MICHELE, PAVIA.

The inclination is about a foot, with return bend to the perpendicular (above the limit of the drawing). (Drawing from a Brooklyn Institute photograph.)

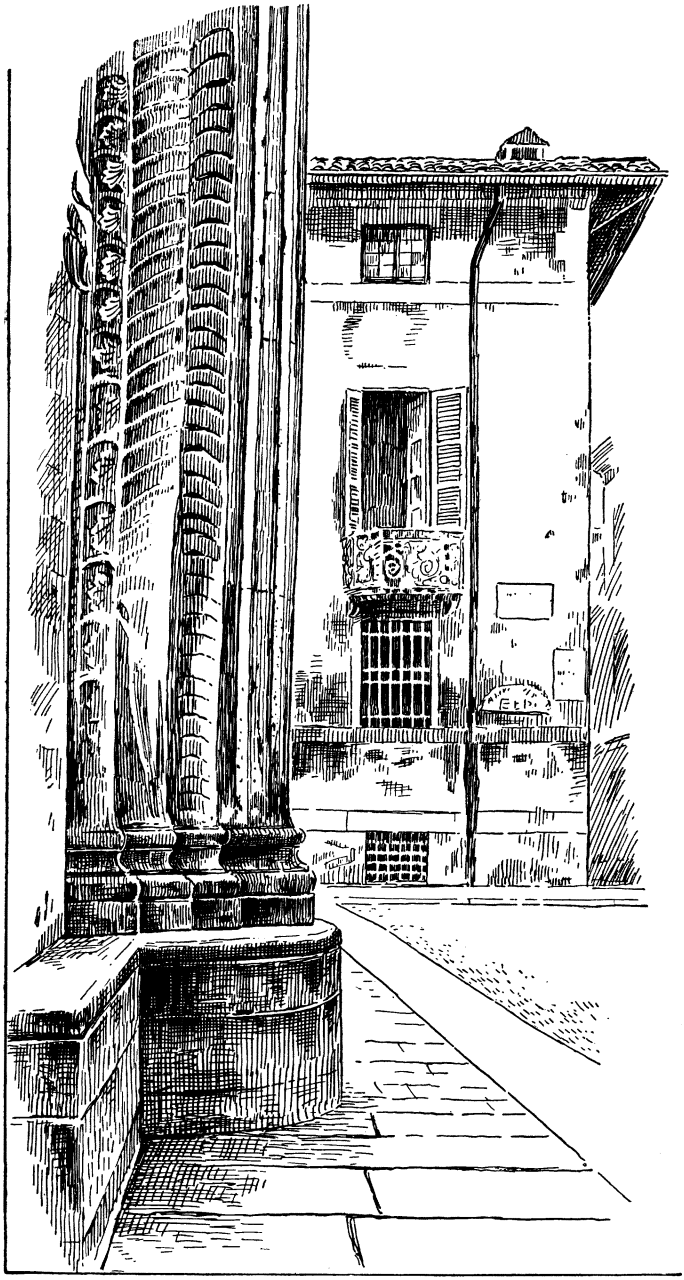

FIGURE 11.—THE LEANING FAÇADE OF S. MICHELE, PAVIA.

Detail showing the upward tilt of the base courses. (Drawing from a Brooklyn Institute photograph.)

vations published by Ranieri Grassi in 1837,[1] but supplement them by additional facts which add to their force and by measurements which he did not supply. Grassi observes that the spiral stairway in the cylindrical wall of the tower is built with gradually increasing height, as it turns from the north to the overhanging south side of the first story. He interprets this as showing the disposition of the builder to add to the weight of the cylindrical wall on the upper side of the lean and to diminish this weight on the overhanging side. He adds that on the south side of the tower the ceiling is tilted up so that, on the south side of the stairway, it is about half a braccio (12 inches) higher than on the north side. This extremely important fact he justly interprets as showing the wish of the builder to throw more of the weight above the ceiling on the inner wall, and less on the outer overhanging wall. No measurements are otherwise given for the heights of the stairway, and no mention is made of the fact that the variations in height continue in the upper stories of the tower. As regards even the first story, the statement is indefinite. It is only said that, if one raises the hand in the stairway on the north side of the tower, it touches the ceiling, and if the hand is raised in the stairway on the south side of the tower, it does not reach the ceiling.

When exact measurements are taken, the following facts appear. The entrance to the spiral stairway on the left of the entrance door is at a point midway between the north and the south sides of the tower, the latter being the overhanging side. At its entrance the stairway has a height of 7.94 feet. On the highest step of the north side (the thirteenth step) the height is 7.63 feet. On the step corresponding to the greatest lean on the south side (the forty-sixth step) the height of the ceiling from the step line is 8.12 feet on the upper side, and 9.17 feet on the lower side. The step inclines with the lean, and dips down 0.34 feet. Thus the south side of the stairway is actually 1.05 feet higher than the north side, in

[1] *Descrizione di Pisa*, vol. II, p. 97.

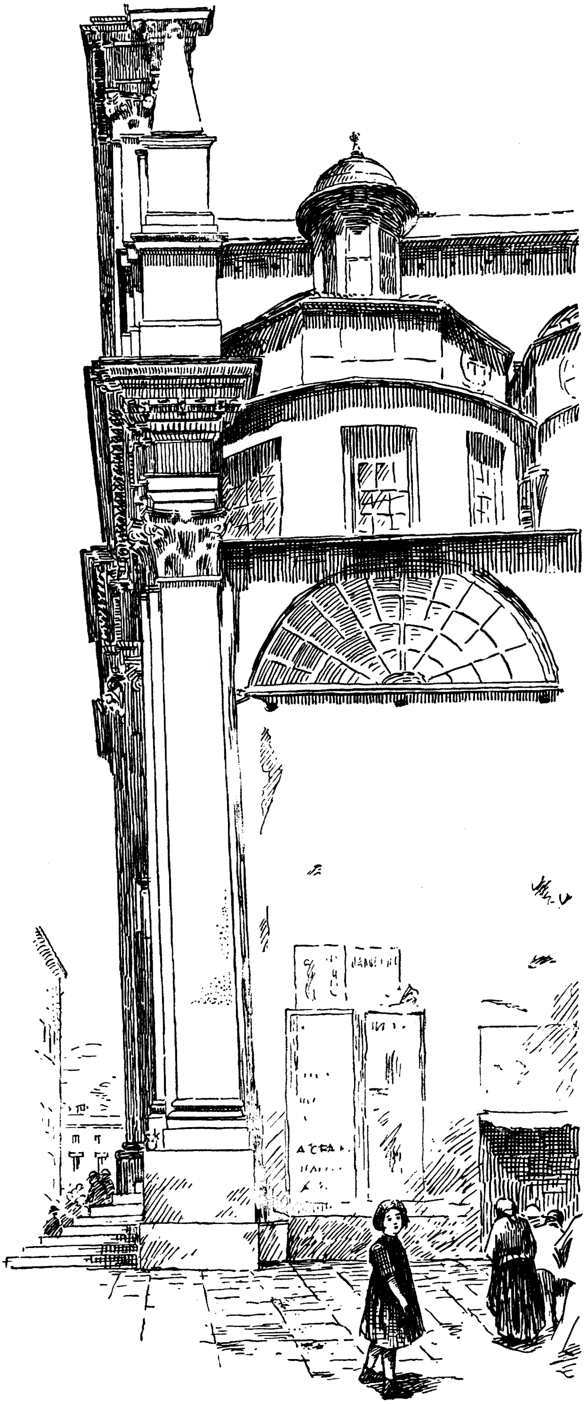

FIGURE 12.—THE LEANING FAÇADE OF S. AMBROGIO, GENOA.

The inclination of the first story is about 8 inches in 56 feet. (Drawing from a Brooklyn Institute photograph.) See appended certificate for construction.

a width of only 3.61 feet. The south side of the ceiling is 0.71 feet (or $8\frac{1}{2}$ inches) above the level of the north side, in this width. Then, adding the two differing measures of the

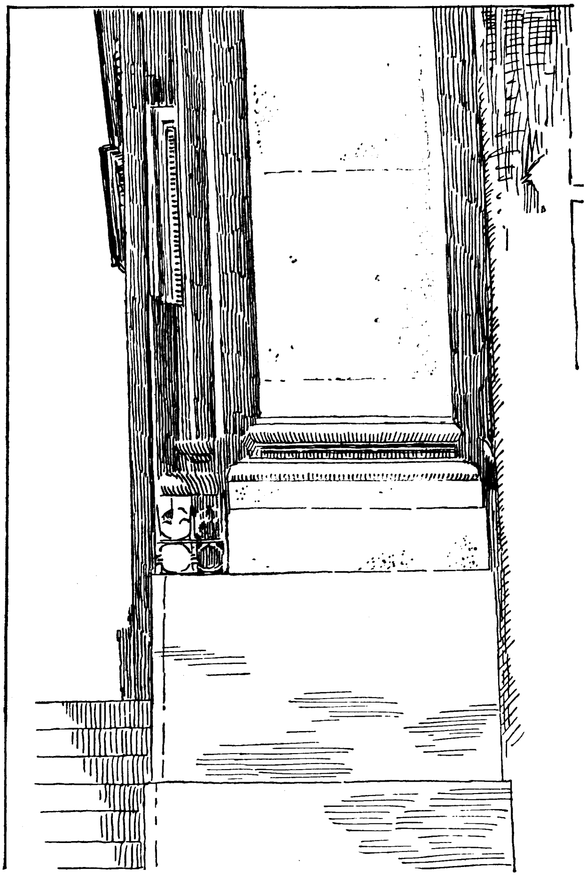

FIGURE 13.—THE LEANING FAÇADE OF S. AMBROGIO, GENOA.
Detail of the base courses, showing an oblique cutting of the pilaster. (Drawing from a Brooklyn Institute photograph.)

walls at this point and dividing by two, to obtain the average or central height of the stairway at this point, we find it to be a foot higher than it is at the thirteenth step.

If we now follow the rising spiral to the north side, it gradually grows lower in height, to the amount of 10 inches (0.84

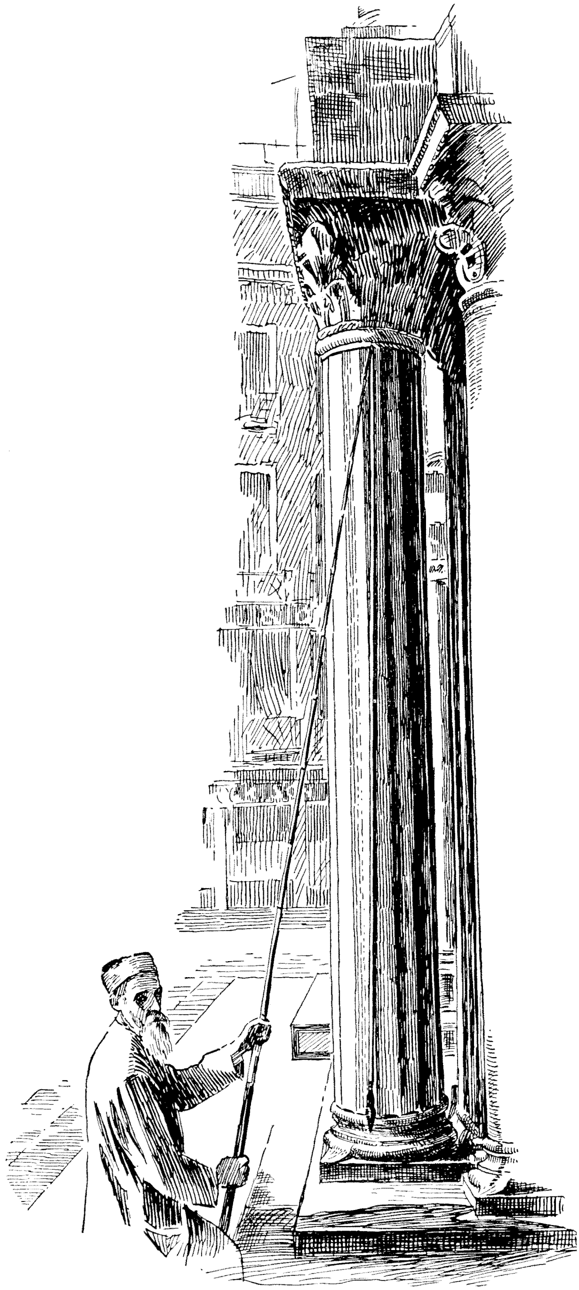

FIGURE 14. — DETAIL OF THE FAÇADE OF ST. MARK'S, VENICE.

The columns lean out from 2 inches to 3½ inches in a height of 9½ feet. (Drawing from a Brooklyn Institute photograph.) See appended certificate for construction.

feet) at the seventy-ninth step. As the spiral turns toward the overhanging south side, the height gradually rises 8 inches (0.65 feet) to the one hundred and fifteenth step (which is about the centre of the overhanging side). In the next half-turn to the north side the height lowers 14 inches (1.18 feet).[1] Beyond this point to the next central point on the south side, there is no appreciable variation; and the spiral stairway ends before another turn is completed.

There are thus four separate changes in the height of the stairway (without counting the difference of about 4 inches between the entrance and the thirteenth step), all of which can be explained on the theory of an intentional inclination, and all of which would be positively incomprehensible on any other theory. To these facts must be added the significant one regarding the inward downward tilt of the stairway ceiling on the overhanging side of the first story. When the delicate masonry arrangements are considered, by which these variations of height and of level are gradually and insensibly obtained, there does not appear to be any explanation possible excepting that of intentional construction.

William H. Goodyear.

Museum of the Brooklyn Institute
of Arts and Sciences.

CERTIFICATES

I

Genova, Piazza Invrea 8.

Sig. Wm. H. Goodyear:

Per aderire al desiderio dalla Signoria vostra espressomi eccomi ad esporle alcune notizie a riguardo della facciata della Chiesa di S. Ambrogio. La detta facciata venne eseguita soltanto in parte, cioè pel tratto inferiore all' epoca della costruzione della chiesa nel 1580, cioè verso la fine del secolo sedicesimo.

[1] There is an intermediate variation between these points, culminating at the centre of the east side in a rise of 18 inches. There is no obvious explanation for this change, and it is the only one which breaks the rule of a graduated and unbroken sequence.

Recentemente, cioè negli anni 1891, 92, 93, per cura e spese del benemerito Prevosto di detta chiesa l' Abbate Poggi, si procedette alla riparazione della parte esistente di detta facciata, ed a completare la medesima venne costrutta a nuovo la parte superiore.

In tale circostanza si ebbe a costatare che la parte inferiore di detta facciata aveva una inclinazione sulla verticale o strapiombo di M. 0.20 circa sopra un altezza approssimativa di M. 15.

Naturalmente la parte superiore venne costrutta senza alcuna inclinazione. L' inclinazione della parte inferiore non si crede debba attribuirsi a spinte interne degli archi o ad altra causa di deterioramento, giacchè in tel caso si avrebbero delle deformazioni parziali sulla detta facciata, mentre invece una tale inclinazione è in certo modo costante su tutta la facciata e le decorazioni della stessa si trovano orizzontali e non inclinati nel senso dello strapiombo. Per cui si deve credere che la stessa sia stata costrutta fin da principio con detta inclinazione.

Ing. Arch. LUIGI DE ANDREIS,
Direttore dei lavori di detta facciata.

GENOVA, li 22 Luglio, 1901.

II

PISA, li 9 Agosto, 1901.

Ill^{mo} Sig. GOODYEAR:

Ho esaminato le misure da Lei prese nei monumenti di Pisa e posso affermare che le prove sono complete per le cose seguenti.

1. Che la facciata della Cattedrale di Pisa è stata inclinata per intenzione nella originale costruzione.
2. Che tutte le curve di questo edificio sono state fatte con intenzione nella originale costruzione, sia le curve orizzontali come quelle verticali.
3. Che le linee oblique delle gallerie interne, sono state costrutte nel modo che oggi si vede.
4. Che la grande cornice esterna è obliqua pure per costruzione.

Con ogni ossequio,
Della S.V. Ill^{ma},
Devot^{mo},
Ing. ANNIBALE MESSERINI.

III

BASILICA DI S. MARCO
IN VENEZIA.
DIREZIONE DEI RESTAURI
E DELLO STUDIO DI MOSAICO.

VENEZIA, 19 Agosto, 1901.

CHIARISSIMO SIGNORE:

Permettemi anzitutto che mi congratuli con Voi degli importanti studi che andate facendo da molti anni sopra i monumenti antichi e in ispecie intorno a certe particolarità di costruzione in gran parte sin qui ignorate

e che rivelano sapienti e ingegnosi artifizi usati dagli architetti che li eressero, per ottenere effetti prospettivi singolari. Già si sapeva come, per esempio, ne' monumenti di architettura medioevale si avesse il costume d' inclinare all' infuori i frontoni e le cuspidi con gli ornamenti sovrapposti, come si fa anche in oggi per i quadri e per le statue. In particolare questo artifizio vedesi usato assai marcatamente nelle cuspidi della facciata principale della nostra Basilica di San Marco; non così in quelle delle facciate laterali, perchè l' architetto che le ricostruì, nei restauri di circa trenta anni or sono, non capì il magistero che aveva presieduto al loro collocamento e le mise a piombo. Lo stesso artifizio vedesi usato nella Porta della Carta del Palazzo Ducale e in tanti altri monumenti anche fuori di Venezia, come per esempio nel Sepolcro degli Scaligeri a Verona. Si sa del pari che nella stessa nostra Basilica la facciata principale è disposta in curva sensibilmente rientrante.

Così i sei minareti della stessa facciata non sono eguali in altezza, ma vanno salendo da una parte e dall' altra verso la cuspide centrale. Che si fa eccezione quello dell' angolo sud-ovest, egli è perchè fu rifatto in seguito ad un incendio e chi lo rifece non s' accorse dell' artifizio e lo costrusse eguale al penultimo.

Voi poi trovaste nuove particolarità di questo genere che io aveva sempre creduto accidentali, ma che essendo comuni a tanti altri monumenti devono accettarsi quali veri artifizi di costruzione. Tali sono le colonne della facciata della nostra Basilica sensibilmente pendenti all' infuori nell' ordine inferiore e a piombo nel superiore. Tali sono pure i piedritti interni sostinenti le volte maggiori che l' inclinano all' indentro, aumentando così notevolmente la corda dell' arco che si corrisponde, in confronto della base, senza che l' arco presenti qualsiasi abbassamento o deformazione; il che dimostrerebbe che così fossero stati disposti fino dall' origine. Tali sono finalmente i parapetti delle gallerie composti a plutei, che vanno da un arcata all' altra lungo le braccia della crociera, i quali sono marcatamente curvilinee con la convessità all' insù. Bisogna certo ammettere che specialmente in quest' ultimo esempio qualche deformazione possa essere stata causata, o per lo meno aumentata, dallo squilibrio dei pesi delle masse murali sopra un terreno cedevole come quello di Venezia. Tuttavia il caso è troppo costante perchè si possa ammetterlo siccome puramente accidentale in via assoluta.

Del resto gli studi che voi andate facendo sono molto interessanti e possono condurre anche ad altre scoperte più importanti ancora; per cui sono a congratularmene e in pari tempo vi prego di credermi quale ho l' onore di professarmi.

Vostro dev. servo,

PIETRO SACCARDO.

Sig. Wm. H. Goodyear, Curatore delle Belle Arti
nel Museo di Brooklyn a Nuova York.